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Testing Global Dietary Convergence

Sri Noor Cholidah
University of Nebraska–Lincoln, srinoorch@huskers.unl.edu

TESTING GLOBAL DIETARY CONVERGENCE

by

Sri Noor Cholidah

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Agricultural Economics

Under the Supervision of Professor Azzeddine Azzam

Lincoln, Nebraska

August, 2018

TESTING GLOBAL DIETARY CONVERGENCE

Sri Noor Cholidah, M.S.

University of Nebraska, 2018

Advisor: Azzeddine Azzam

Historical evidence shows that compared to Western countries, where the nutrition transition from a diet heavy in starchy staples to the modern Western diet took more than two centuries, the nutrition transition in developing countries towards Western-type diets has taken only a few decades, suggesting a trend towards global dietary convergence. This thesis explores the extent of such convergence by measuring β-convergence and σ-convergence of diets of 152 countries using FAO data on total calorie intake and calories by source from 1961-2009.

Results for β-convergence show that a) countries who started in 1961 with lower calorie intake, in total or by source, are catching up to countries who started with higher calorie intake, and b) convergence speed is highest for total calories, followed by calories from oils, vegetables, cereals, sweeteners, roots, fruits, animals, and pulses. Results from σ-convergence show a narrowing of variation across countries in total calories and calorie proportions from the eight sources. Both sets of results confirm a trend towards global dietary convergence.

Findings of convergence reveal that dietary structure across countries is becoming increasingly similar, although at differing speeds, and depending on a country’s latitude. Should this translate to continued transformation of developing countries’ food systems from traditional to Western-type patterns, one should expect further negative consequences for health and the environment.

ACKNOWLEDGMENTS

Sending my gratitude to God Almighty for all the opportunities, protection, guidance and blessing during the entire study.

Next, I would like to convey my appreciation to USAID Prestasi for the funding. I am thankful to be USAID Prestasi awardee.

My sincerest gratitude goes to my advisor, Dr. Azzeddine Azzam for his guidance, encouragement, and patience over the last two years. I am especially thankful to him because he opened my mind to a thousand new things. He gave me the energy and confidence when I did not have them.

Special thanks to Colin Khoury of the International Center for Tropical Agriculture for pointing me and my advisor to the dataset used in this thesis.

I would like to thank Dr. Christopher R. Gustafson and Dr. Georgia Jones for serving as my committee members.

Lastly, I would like to thank my family and friends, this study would not be possible without their prayers and everlasting support.

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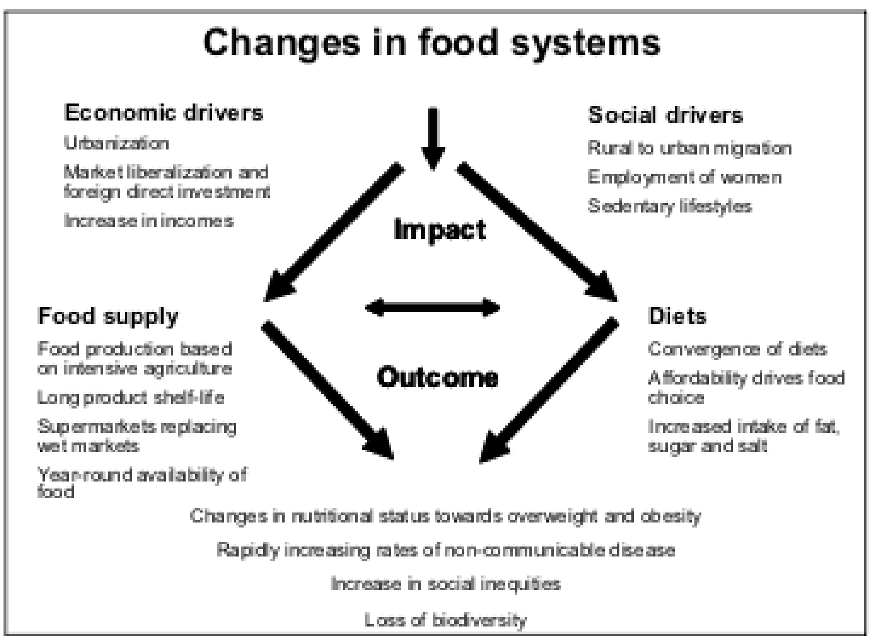
Introduction

1.1 Statement of the problem

Over the past two decades, there has been increasing evidence of and concern over the role of globalization in the transformation of developing countries' diets and food supply from traditional to Western-type patterns (Drewnowski and Popkin 1997; Kennedy et al. 2004; Pingali 2006, HLPE 2017). There are economic and social factors behind the changes. As shown in Figure 1.1, economic factors include urbanization, market liberalization, foreign direct investment and increase in income. Social factors include employment of women and sedentary lifestyles.

Figure 1.1 Changes in Food Systems



Source: Kennedy et al. 2004, p.2.

The changes in food production in developing countries permeate all stages of the food supply chain linking farmers to consumers (HLPE 2017). Food is produced using more intensive use of energy-based inputs, highly processed, and increasingly sold through supermarket and fast food franchises from Western countries (Pingali 2006). Resulting increases in the affordability, availability, and the quantity of foods has led to what has become known since the 1990's as the "nutrition transition" (Drewnowski and Popkin 1997) or "Westernization" of diets (Pingali 2006).

The nutrition transition is characterized by a diet that is higher in fat, sugar, and lower in energy from complex carbohydrates (Drewnowski and Popkin 1997). Compared to Western countries, where the nutrition transition from a diet heavy starchy staples to the modern Western diet took more than two centuries, the nutrition transition in developing countries towards Western-type diets has taken only a few decades (Grigg, 1995; Drewnowski and Popkin 1997; Uusitalo et al. 2002). This suggests a trend towards global dietary convergence.

The two main characteristics of diets globally are reliance on a narrow base of staple grains, and increased consumption of meat and meat products, dairy products, edible oils, salt and sugar, and a lower intake of dietary fiber. (Kennedy et al. 2004, p.9). A consequence of a narrow base of staple grains is loss biodiversity, potentially threating food security (Khoury et al. 2014). A consequence of shifts to a diet higher in fats, edible oils, salt and sugar is the spread of non-communicable diseases such as diabetes, obesity, heart diseases, hypertension and certain types of cancer (Drewnowski and Popkin 1997; Khoury et al. 2014; Kearney 2010; Pingali 2006).

The focus of this thesis is dietary convergence. The thesis contributes to the literature on globalization and food systems by determining the extent of β-convergence and σ-convergence of diets across-countries. Studies related to dietary convergence are limited and have different objectives, methodology and geographical area (Blandford 1984; Gil et al. 1995; Herrmann and Roder 1995; Regmi and Unnevehr 2006; Brunelle et al. 2014; Khoury et al. 2014). As discussed in the literature review section, only two studies, Gil et al. (1995) and Regmi and Unnevehr (2006), considered convergence and used the same methodology used in this thesis. However, with the exception of Khoury et al. (2014), who considered similarity, rather than convergence, between national food supplies worldwide; and Brunelle et al., (2014) who simulated consequences of hypothetical global convergence to a Western diet, convergence studies are dated and only focus on the European Union and high-income countries.

1.2 Objective

The objective of this thesis is to investigate cross-country dietary convergence in terms of total calories and the percentage of total calories from animal products, cereals, oils, sweeteners, pules, fruits, vegetables, and roots. For methodology, two convergence indicators are computed: β-convergence and σ-convergence for 152 countries from 1961 to 2009 using the Food Balance Sheets of the Food and Agriculture Organization. β-convergence means that countries with higher (lower) initial amount of per-capita of food consumption, measured in calories, in total or by source, experience slower (faster) growth than countries with lower (higher) initial amounts. σ-convergence means that a narrowing of the spread of calories, in total or by source, across countries and time implies dietary convergence.

1.3 Organization of the study

The next chapter reviews the literature on dietary convergence. Chapter 3 discusses convergence methodology and its applications. Chapter 4 presents the data.

Chapter 5 specifies the model and presents the statistical results. Summary and conclusion are in the final chapter.

Chapter 2
Review of Literature on Dietary Convergence

The literature pertinent to dietary convergence is limited. Blandford (1984) examined the trends in food consumption patterns in the OECD countries using data on per capita consumption in calories, changes in total consumption and the share of animal products. Cluster analysis was used to determine country groupings based on the similarities in dietary structure. Results show that, while the proportion of calories from animal-based products increased, the proportion of calories from plant-based products declined in most OECD countries, indicating that they share a similar dietary structure.

Gil et al. (1995) analyzed the trends in food consumption patterns in Western European countries using data on per capita calorie intake from the Food and Agriculture Organization of the United Nations (FAO) and real per capita income from the International Monetary Fund. The authors first used cluster analysis to get the degree of similarity in the evolution of the structure of calorie intake across countries. After that they tested for β-convergence and σ-convergence. Convergence was found in the proportion of total calories derived from the main food groups, indicating similarity in European diet. Results from β-convergence were positive, indicating that consumption in countries with lower initial calorie intakes experience faster growth than countries with higher initial calories intake. On the other hand, results of the σ-convergence show that the speed of the convergence has decreased from 1970 to 1990.

Building on research from two previous studies, Herrmann and Roder (1995) focus on converging food consumption patterns, their determinants and the evolution of food demand in OECD countries. The data used in the analysis include calories, protein and fat intake from OECD food consumption statistics. Findings suggest a tendency towards convergence of per capita demand of the main food components in OECD countries. The concept of relative convergence refers to the decrease in relative differences across the food consumption of different countries. Absolute convergence, in contrast, denotes absolute differences in per capita food consumption as they decrease over time. Results show that relative convergence of calories, protein, and fat was found in the nutrient demand from all food products including animal products. On the other hand, absolute convergence of calories and protein demand was found only in crop products. Even though differences between absolute and relative convergence still exist in food consumption across countries, no divergence was found in any single case.

Regmi and Unnevehr (2006) investigated converging food demand in 18 high income countries from 1990 to 2004 using Euromonitor data for all food and for several product categories. Convergence was tested using σ-convergence and was not found in all categories. It was found in total food expenditure and other food-expenditure categories from cereals, meats, fish and vegetables. This, the authors believe, suggests convergence in tastes and preferences.

Brunelle et al. (2014) utilized the NLU land-use model to examine the spectrum of possible future diet evolution and their agricultural consequences. The impact on agriculture was evaluated based on different presumptions of the impacts of globalization on dietary changes. Their findings indicated that animal calories represent the highest span of future diet convergence, while the highest ecosystem impacts are related with the greatest convergence towards Western diets.

The most recent study related to convergence of diets was conducted by Khoury et al. (2014). Using the same dataset used in this thesis, the authors catalogued national per capita food supplies in total quantities of food calories, proteins, fat, and weight over the course of 50 years for 53 crop commodities worldwide. Using Pielou's evenness and Bray-Curtis dissimilarity indices, the authors found that national food supplies increased in measured crop commodity richness and evenness, while the dominance of most important crop plants decreased, suggesting increased similarity in national food supplies.

Overall, previous studies have identified similarity in dietary structure and increasing similarity in national food supplies, as well as convergence in total calories and certain calorie sources. With the exception of Khoury et al. (2014), which was worldwide, but focused on similarity rather than convergence of national food supplies, the focus of most past research is on OECD countries, European countries, and high-income countries.

Chapter 3
Convergence Methodology and Its Application

The concept of convergence was originally conceived and applied in the context of economic growth across countries. According to neoclassical growth theory model pioneered by Solow (1956), poor countries with the lowest initial income per capita would grow more quickly and then catch up eventually to wealthier countries, leading to convergence in terms of per capita income across countries. Other studies by Barro (1991) and Baumol (1986) used a cross-sectional approach to test whether convergence across countries has taken place.

The two forms of convergence commonly used in the economic growth literature are β-convergence and σ-convergence. β-convergence refers to any data series that starts out with higher (lower) initial values and experiences slower (faster) growth than series with lower (higher) initial values. Stated differently, β-convergence refers to a pattern of 'catching-up', or even 'leap-frogging'. It is assessed by the sign and statistical significance of the coefficient on the initial values. A negatively sloped and statistically significant coefficient implies an inverse relationship between the rate of change between periods in a data series and its initial values of the series. σ-convergence denotes the spread of cross-sectional distribution of a group of series over time. The presence of σ-convergence is measured by the magnitude of coefficient of variation, suggesting that over time the data distribution is moving together more closely. A narrowing distribution implies σ-convergence.

Following Barro and Sala-i-Martin (1992), thee basic regression model used for testing β-convergence in cross-country growth convergence is as follows:

$$\frac{1}{T}\,log\left(\frac{y_{i,t_0+T}}{y_{i,t_0}}\right) = a - \left(\frac{1-e^{-\beta T}}{T}\right)\log\left(y_{i,t_0}\right) + \ u_{i,t_0,t_0+T} \qquad (1)$$

where

$Y_{i,t0}$ = per capita income in country *i* in year t_0

$Y_{i,t0+T}$ = per capita income in country *i* in year $t_0 + T$

T = period length

β = speed of convergence

$u_{i,t0,t0+T}$ = distributed lag of the error terms, u_{it} between years t_0 and $t_o + T$.

a = constant term of *i* given growth rate representing steady state level of Y

If β-convergence exists, $\left(1 - e^{-\beta T}\right)$ must be positive and this requires $\beta > 0$. To examine σ convergence, the coefficient of variation $CV_t = \frac{\sigma_t}{u_t}$ is computed across countries for each year, where σ_t and u_t are the standard deviation and mean, respectively.

Applications of convergence methodology are not limited to economic growth. Other applications include incidence of obesity (Li and wang 2016), productivity growth (Apergis and Christou 2016; Bernard and Jones 1996; Hussain and Bernard 2016; Carree et al. 2000; Sondermann 2014), carbon dioxide emissions (Mohammadi and Ram 2012); energy consumption (Mohammadi and Ram 2016), and criminal activity (Cook and Winfield 2011).

Chapter 4
World Dietary Data

The data used in this thesis to test for cross-country diet convergence is extracted from the International Center for Tropical Agriculture's "The Changing Global Diet" website (CIAT, undated). Based on Food Balance Sheets (FAOSTAT) assembled by the Food and Agriculture Organization (FAO) of the United Nations, the data from CIAT reports two categories of caloric intake at the country level: per-capita calories per day in total calories and percentage of total calories from eight sources for 152 countries over the period 1961-2009, covering every country in the world. The eight sources of calories are animal products, cereals, fruits, crop oils (hereafter oils), pulses (also known in the US as legumes), roots, sweeteners, and vegetables. The composition of the eight sources is described in detail by CIAT (undated).

For lack of consistent dietary data at the household level across countries, the FAO Food Balance Sheet data, which represents food available for human consumption, are often used to represent cross-country dietary patterns (Berners-Lee et al. 2012; Eshel and Martin 2006; Khoury 2014; Tukker et al. 2011; Rehkamp et al. 2017). Food availability is defined by FAO as domestic supply (production + imports + stocks – exports) net of feed, seed, industrial uses, and waste (FAO 2018).

Using caloric equivalents of food consumption has both advantages and disadvantages. On the one hand, it makes the aggregation of different foods and the derivation of shares by foodstuff type simpler. Furthermore, as Gil et al. (1995) and Blandford (1984) have pointed out, calories have the benefit of being a physical measure that is assumed to be common across nations, which makes the cross-country comparison of consumption changes easier. Nevertheless, the use of caloric equivalents can also be limiting because implementing a common set of caloric conversion factors allows that conversion factors may change both over time and among different nations.

To explore if the data implies dietary convergence, Figures 4.1 through 4.9 show the relationship between growth of calories and initial calories rates across 152 countries over the period 1961-2009. The respective figures represent total calories, calories from cereals, animal products, oils, sweeteners, roots, fruits, pulses, and vegetables. In all cases the relationship is negatively-sloped implying β-convergence; i.e., countries with higher (lower) initial amount of per-capita of food consumption, measured in calories, in total or by source, experience slower (faster) growth than countries with lower (higher) initial amounts.

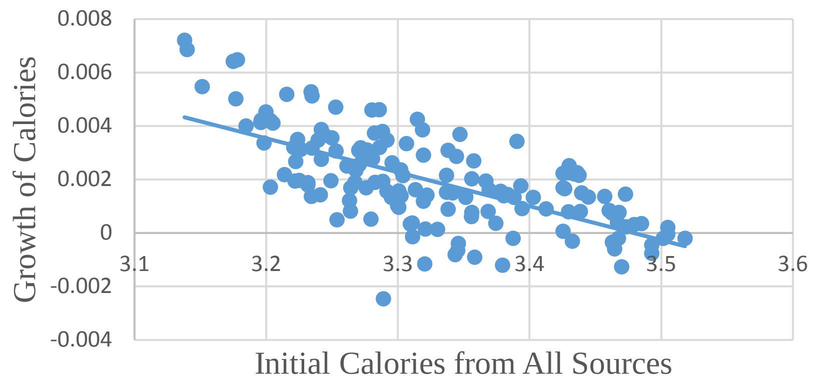


Figure 4.1. Growth Rates and Initial Calories From All Sources 1961-2009

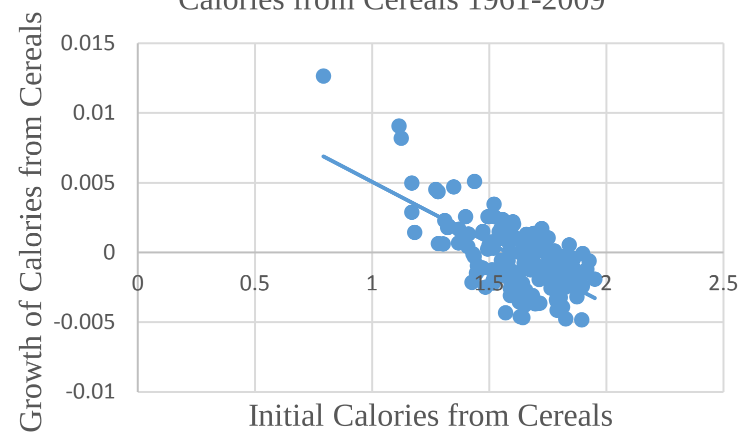


Figure 4.2 Growth of Calories and Initial Calories from Cereals 1961-2009

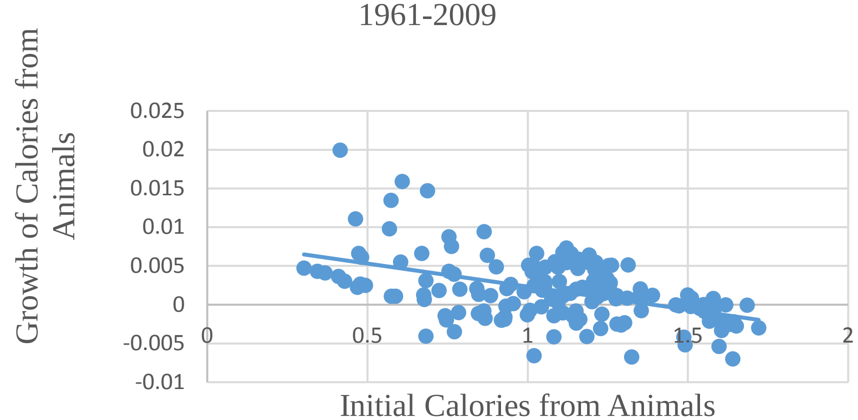


Figure 4.3 Growth of Calories and Initial Calories from Animals 1961-2009

Figure 4.4 Growth of Calories and Initial Calories from Oils 1961-2009

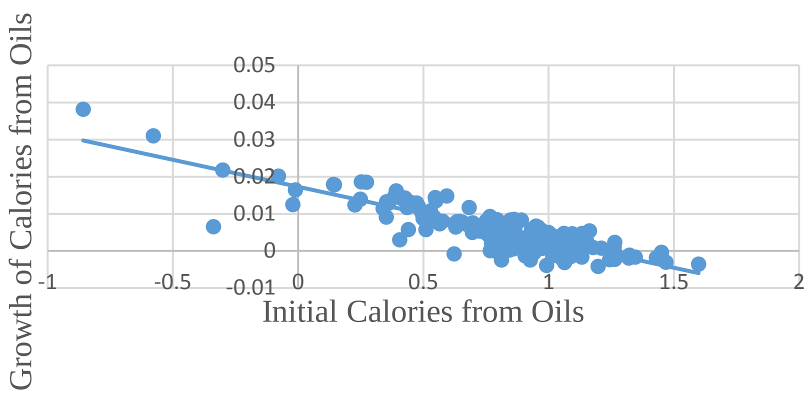


Figure 4.5 Growth of Calories and Initial Calories from Sweeteners 1961-2009

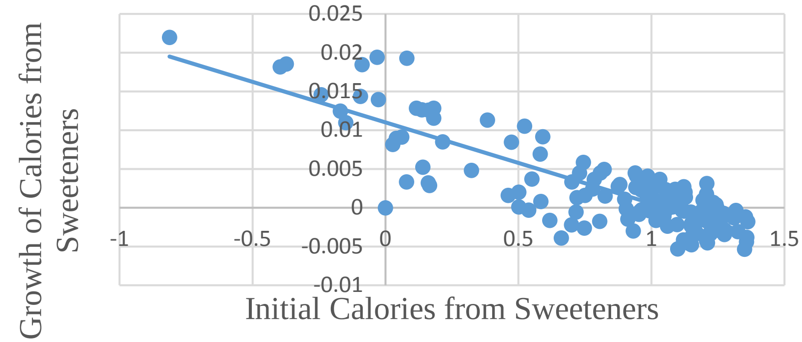
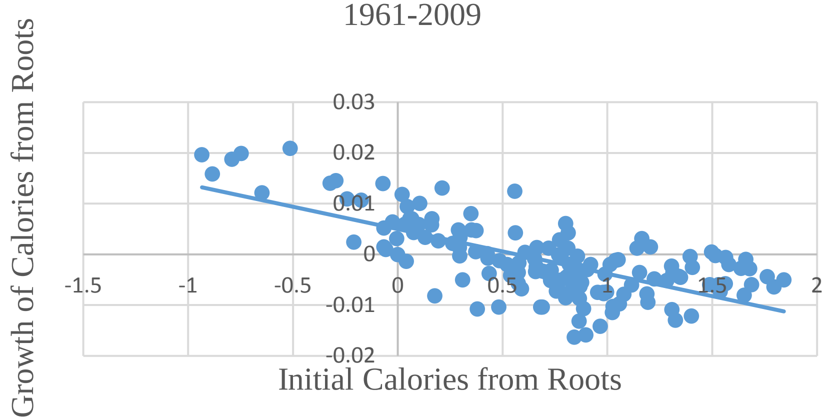


Figure 4.6. Growth of Calories and Initial Calories from Roots 1961-2009



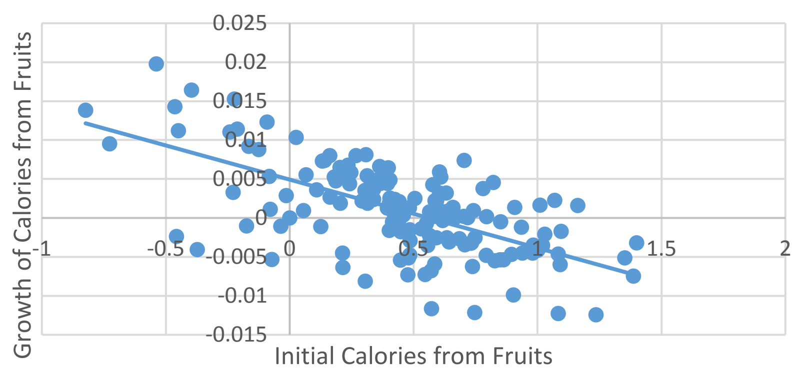


Figure 4.7 Growth of Calories and Initial Calories from Fruits 1961-2009

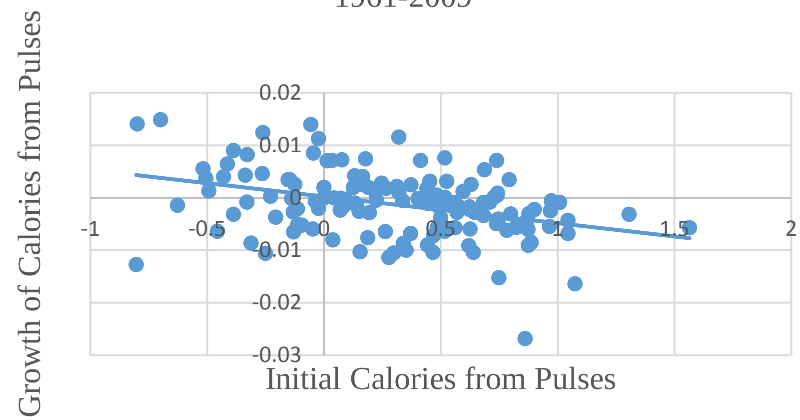


Figure 4.8 Growth of Calories and Initial Calories from Pulses 1961-2009

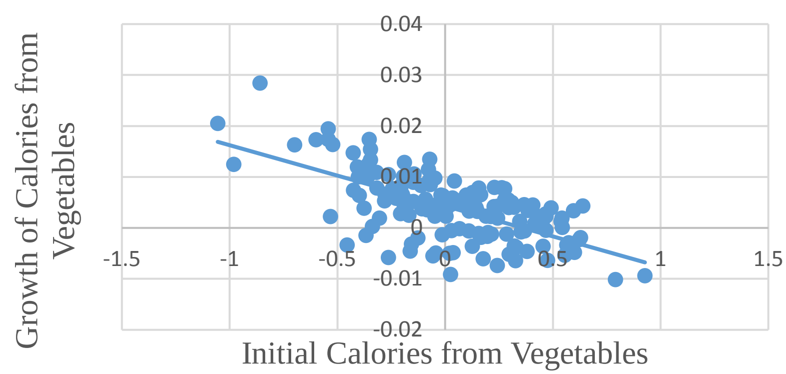


Figure 4.9 Growth of Calories and Initial Calories from Vegetables 1961-2009

Chapter 5
Model and Results

5.1 Model

To statistically test for β-convergence suggested by the graphs in the previous chapter, the following extended version of equation (1) in chapter (3) is used:

$$\frac{1}{T}\,log\left(\frac{y_{i,t_0+T}}{y_{i,t_0}}\right) = a - \left(\frac{1-e^{-\beta T}}{T}\right)\log\left(y_{i,t_0}\right) + \gamma\; latitude_{\mathrm{i}} + u_{i,t_0,t_0+T} \qquad (1')$$

$Y_{i,t0}$ = total per capita calorie intake in country *i* in year t_0

$Y_{i,t0+T}$ = total per capita calorie intake in country *i* in year $t_0 + T$

T = period length

β (γ) = speed of convergence (latitude effect)

$Latitude_i$ = the *i*th country's latitude

$u_{i,t0,t0+T}$ = distributed lag of the error terms, u_{it} between years t_0 and $t_o + T$.

a = constant term of *i* given growth rate representing steady state level of Y

In this extended equation, $Latitude_i$ designates the *i*th country's latitude (obtained from the World Fact Book (CIA). Following de Boer, Helms, and Aiking (2006), latitude is "a proxy for differences in climate, vegetation, and historical development" (p. 269). Latitude is also positively correlated with growth in income (Acemoglu et al. 2005).

If β-convergence exists, $\left(1 - e^{-\beta T}\right)$ must be positive, and this requires β > 0 as shown in Gil et al. (1995). For σ convergence, the coefficients of variation $CV_t = \frac{\sigma_t}{u_t}$ is computed for each year and examined for trend across 152 countries; with σ_t and u_t denoting the standard deviation and mean of yearly caloric intake, respectively.

5.2 Results

5.2.1 β-Convergence

The β-convergence results generated by the estimation of Equation 1 using nonlinear least squares (SAS Institute Inc 2011) are reported in Table 1 for total calories and eight calorie sources of calories from 1961 to 2006. The main focus is thus the estimated coefficient of β-, with a positive value indicating the presence of β-convergence. Suspecting heteroscedasticity, the Breusch-Pagan and White tests are employed when estimating Equation 1. The White test is more general than the Breusch-Pagan test, and while the White test explores heteroscedasticity, it may also identify other specification errors.

The results obtained from both tests for heteroscedasticity are presented in Table 1. Under the null hypothesis of homoscedasticity, the critical value at the 5% level of significance is 5.99. Since all the calculated chi-square values from White test are greater than 5.99, the null hypothesis of homoscedasticity for total calories and proportion of calories from eight sources is rejected. Under BP, however, the null hypothesis is not rejected for total calories and roots. The point estimates of the β's suggest that the speed of convergence is highest for total calories, followed by oils, vegetables, cereals, sweeteners, roots, fruits, animals, and pulses.

Since the form of heteroscedasticity is unknown, generalized method of moments estimation (GMM) is used for improving the efficiency of parameter estimation (Greene 2012; SAS Institute Inc 2011). The GMM coefficients of β-convergence from total calories and all sources of calories reported in Table 2 are similar in magnitude and statistical significance as their counterparts in Table 1, preserving the rankings in terms of speed of convergence.

The results are consistent with the scenario in Figures 4.1 through 4.9 which depict the negatively-sloped relationship between initial calories and average growth rates. More specifically, the results illustrate β-convergence, indicating higher average growth rates in countries with lower initial calories and a lower rate of increase in countries with higher initial calories. Furthermore, β-convergence results are also statistically significant for the proportion of total calories from eight different sources.

Table 2 also shows the relationship between average growth and latitude. The results are similar as those in Table 1. As seen in the column labeled γ for the total calories, the *t* value is 4.27 and is statistically significant at 5%, suggesting a strong association between the average growth rates for total calories and country location on the globe. More specifically, this suggests that the further away a country is located from the equator, the greater the average growth of rate for total calories. Similar results also found for the proportion of total calories from animal products, oils, sweeteners, fruits, and vegetables. However, the *t*-statistics for cereals, roots, and pulses are not significant, indicating that there is no correlation between country location and average growth rates of calories from these categories.

Table 1.
Nonlinear Ordinary Least Squares Results with White and Breusch-Pagan Rest Statistics.

	1961-2009					
	a	β	γ	R^2	WT	BP
Total Calories	0.109	0.022	0.00004	0.511	10	3.03
	(12.78)	(6.83)	(4.71)			
Cereals	0.07	0.013	-0.00002	0.435	8.89	7.59
	(11.05)	(7.45)	(-0.99)			
Animals	0.046	0.008	0.0001	0.311	30.42	21.15
	(9.7)	(6.55)	(3.06)			
Oils	0.081	0.021	0.00006	0.686	59.17	26.6
	(22.32)	(10.36)	(2.36)			
Sweeteners	0.059	0.013	0.00003	0.711	30.77	19.18
	(22.21)	(13.49)	(1.48)			
Roots	0.048	0.013	-0.00005	0.564	9.64	1.62
	(13.48)	(9.86)	(-1.11)			
Fruits	0.041	0.011	0.0001	0.405	23.35	17.85
	(10.65)	(7.22)	(3.04)			
Pulses	0.024	0.007	-2.34E-6	0.166	20.98	8.28
	(5.25)	(4.39)	(-0.05)			
Vegetables	0.046	0.017	0.0002	0.417	10.28	9.84
	(12.56)	(6.39)	(5.31)			

[1] Values in parentheses are t-statistics
[2] WT is the White test and BP is the Breusch-Pagan test for heteroscedasticity. Critical value at 5 % level of significance is 5.99
[3] Number of observations: 152

Table 2.
Generalized Method of Moments Estimation Results.

	1961-2009			
	a	β	γ	R^2
Total Calories	0.109	0.022	0.00004	0.511
	(12.24)	(6.52)	(4.27)	
Cereals	0.07	0.013	-0.00002	0.435
	(8.72)	(5.95)	(-1.07)	
Animals	0.046	0.008	0.0001	0.311
	(7.85)	(5.67)	(3.22)	
Oils	0.081	0.021	0.000067	0.686
	(12.96)	(6.42)	(2.04)	
Sweeteners	0.059	0.013	0.000036	0.711
	(17.1)	(10.98)	(1.6)	
Roots	0.048	0.013	-0.00005	0.564
	(12.72)	(9.69)	(-1.43)	
Fruits	0.041	0.011	0.00011	0.405
	(7.79)	(5.59)	(3.23)	
Pulses	0.024	0.007	-2.34E-6	0.166
	(3.77)	(3.36)	(-0.05)	
Vegetables	0.046	0.017	0.00022	0.417
	(11.42)	(6.02)	(4.78)	

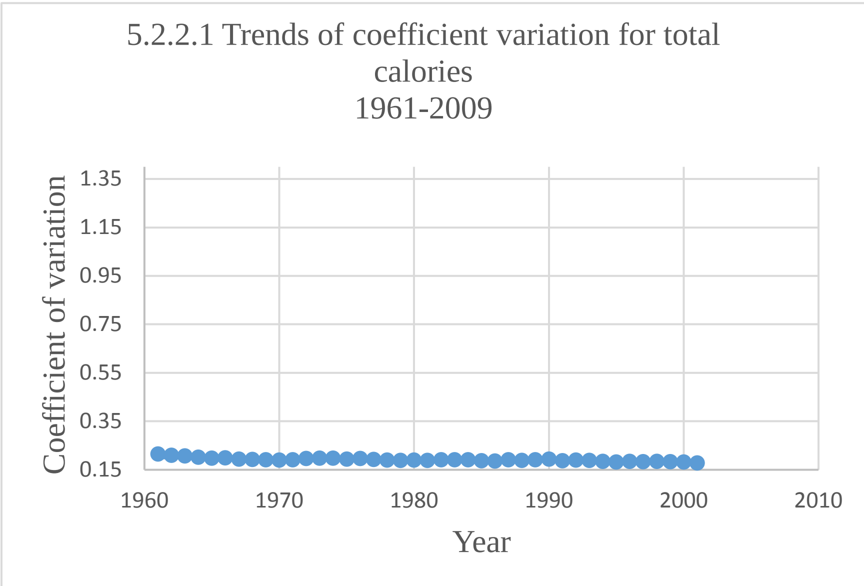
[1] Values in parentheses are t-statistics.

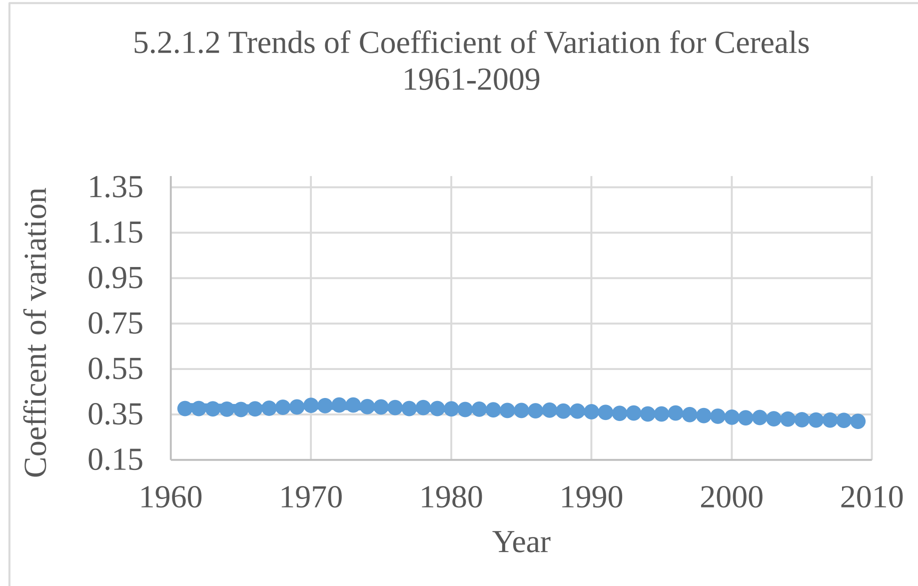
5.2.2 Sigma Convergence

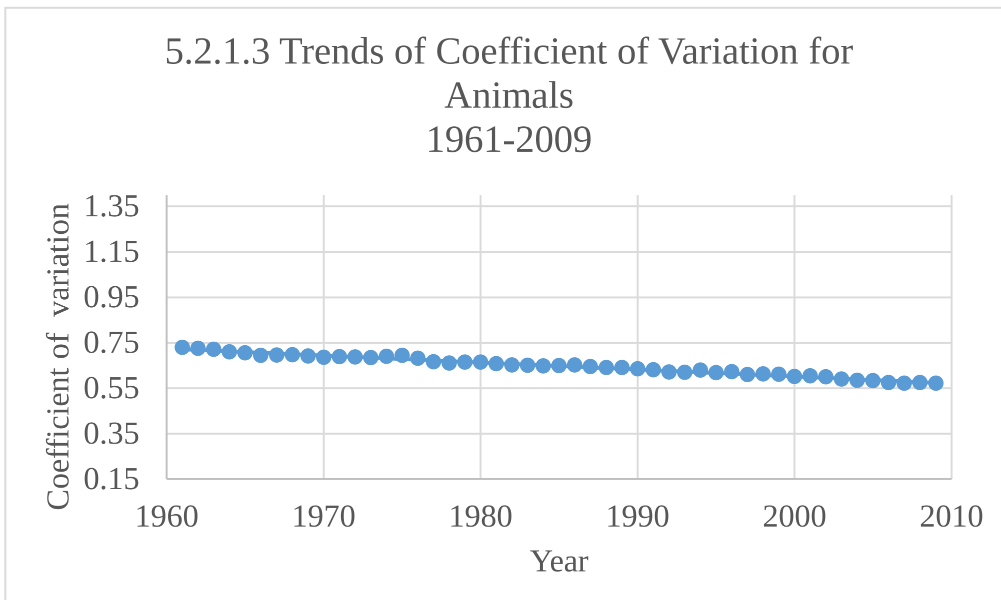
The coefficient of variation (CV) is calculated across the 152 countries and plotted for total calories and the proportions of calories by source for each year from 1961 to 2009. The plots are shown in figure 5.2.1.1 through 5.2.1.9. To permit comparison of the trends in the coefficient of the proportions of calories by source, the range of the vertical axes is set such the smallest (largest) value is equal to smallest (largest) CV among all sources. The smallest CV was 0.32 for cereals and the largest was 1.35 for pulses.

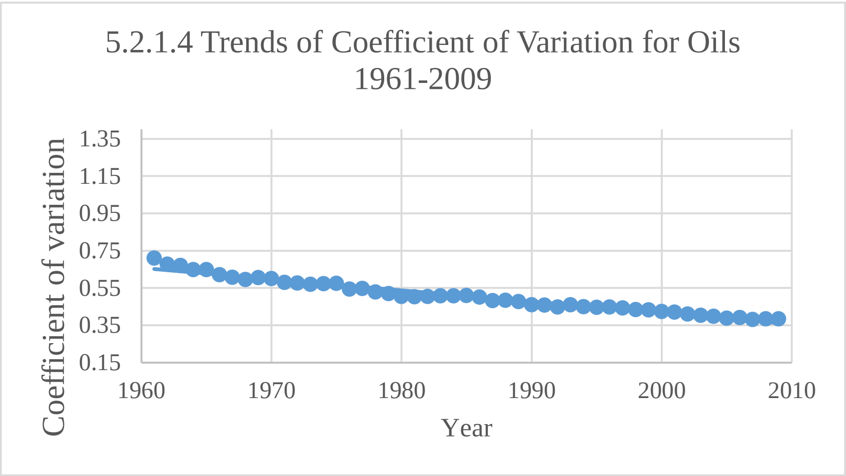
Based on the results of this plotting, a pattern of σ convergence is clearly apparent in figures. The most prominent feature is the sizeable reduction of CV from the proportion of calories from oils, which decreases from 0.71 to 0.38 between1961 and 2009. However, coefficient of variation based on the proportion of calories from cereals and roots is seen to stabilize from 1961 to 2009.

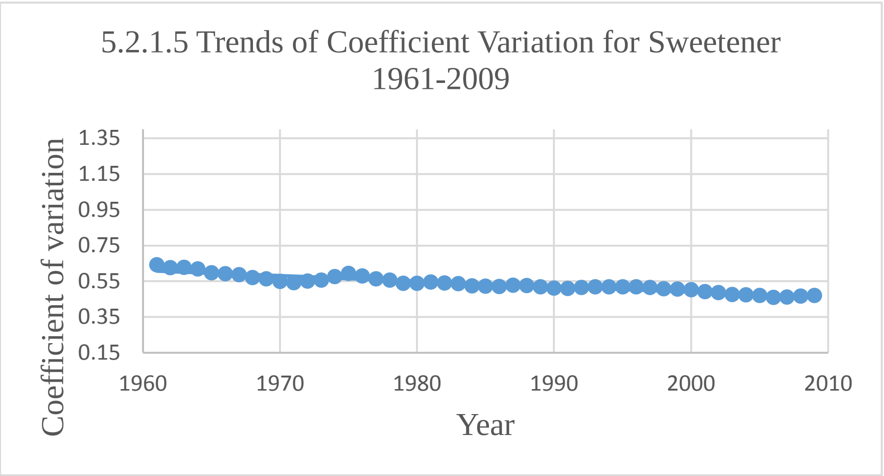
On the other hand, compared to the other categories, the category of total calories shows the lowest value of coefficient of variation, which started at 0.21in 1961 then decreased to 0.16 in 2009. The plots for animals, sweeteners, fruits, and vegetables in Figure 5.2.1.3, 5.2.1.5, 5.2.1.7, and 5.2.1.9 respectively, show steady convergence. Convergence is clearly apparent in both categories, more specifically it is apparent in the proportion of total calories from animals where the coefficient of variation decreases from 0.73 to 0.57 by the end of 2009. The graph for pulses is notable, as the coefficient of variation increases in 1961 until the mid-1970s but then falls to 1.03 in 2009. Overall, the findings catalogued in Figure 5.2.1.1 through 5.2.1.9 are consistent with the results in Tables 1 and 2, which indicate a convergence in diet structure across countries.

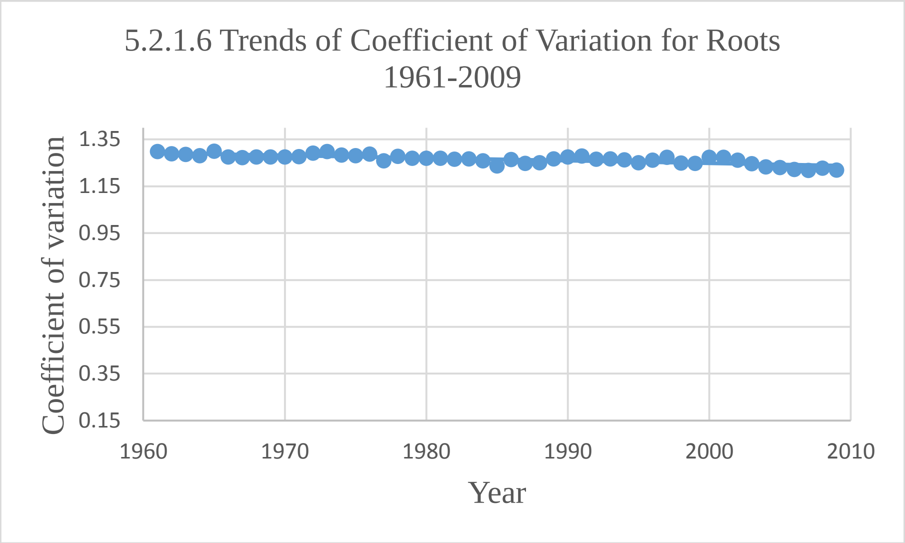

5.2.2.1 Trends of coefficient variation for total calories
1961-2009
Coefficient of variation
1.35
1.15
0.95
0.75
0.55
0.35
0.15
1960
1970
1980
1990
2000
2010
Year


5.2.1.2 Trends of Coefficient of Variation for Cereals
1961-2009
Coefficent of variation
1.35
1.15
0.95
0.75
0.55
0.35
0.15
1960
1970
1980
1990
2000
2010
Year

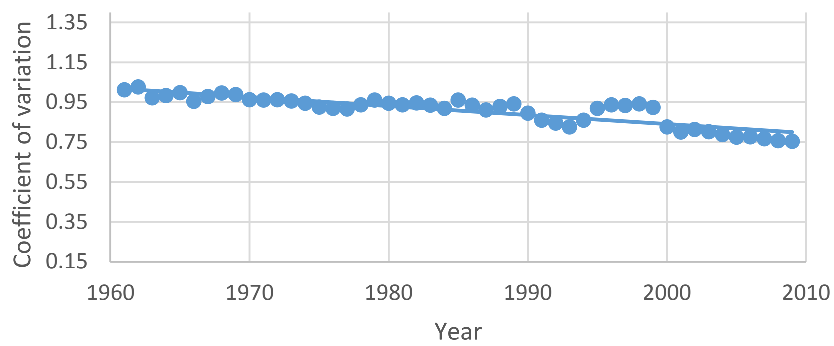

5.2.1.3 Trends of Coefficient of Variation for Animals
1961-2009
Coefficient of variation
1.35
1.15
0.95
0.75
0.55
0.35
0.15
1960
1970
1980
1990
2000
2010
Year


5.2.1.4 Trends of Coefficient of Variation for Oils
1961-2009
Coefficient of variation
1.35
1.15
0.95
0.75
0.55
0.35
0.15
1960
1970
1980
1990
2000
2010
Year

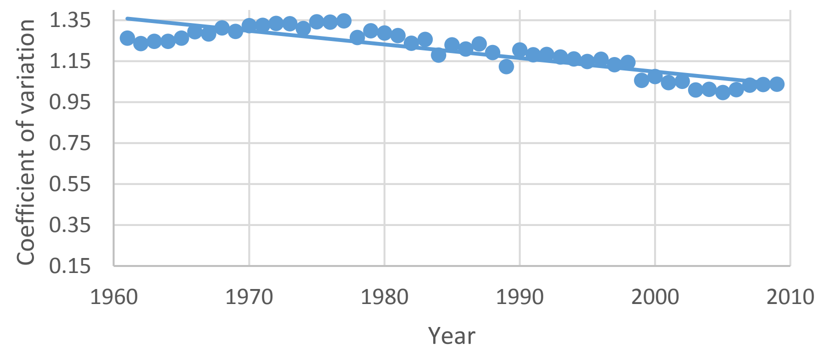

5.2.1.5 Trends of Coefficient Variation for Sweetener
1961-2009
Coefficient of variation
1.35
1.15
0.95
0.75
0.55
0.35
0.15
1960
1970
1980
1990
2000
2010
Year


5.2.1.6 Trends of Coefficient of Variation for Roots
1961-2009
Coefficient of variation
1.35
1.15
0.95
0.75
0.55
0.35
0.15
1960
1970
1980
1990
2000
2010
Year

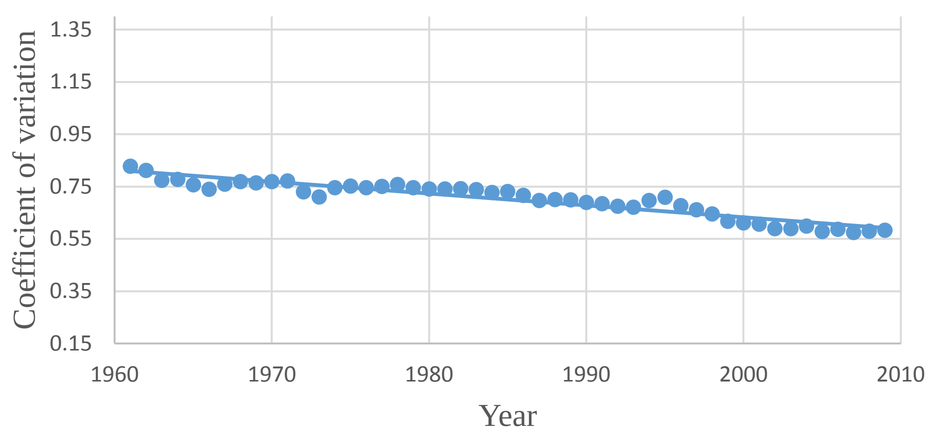
5.2.1.7 Trends of Coefficient of Variation for Fruits
1961-2009



5.2.1.8 Trends of Coefficient of Variation for Pulses
1961-2009



5.2.1.9 Trends of Coefficient of Variation for Vegetables
1961-2009



Chapter 6
Summary and Conclusion

Developing countries' diets and food supply are increasingly shifting from traditional to western patterns as a consequence of globalization over the past two decades. While there are economic and social factors behind these changes in food systems, the shift in food production in developing countries includes all stages of the food supply chain linking farmers to consumers. As a result, food is produced though a more intensive use of energy-based inputs, highly processed, and increasingly sold through supermarket and fast food franchises from Western countries. The consequences of this increase in the affordability, availability, and the quality of food has led to the so-called "nutrition transition" or "westernization" of diets.

While the nutrition transition in developing countries towards Western-type diets has taken only a few decades, the nutrition transition from a diet heavy in starchy staples to the modern Western diet took more than two centuries in Western countries, suggesting a trend toward global dietary convergence. There are two main characteristics of diets globally: a reliance on a narrow base of staple grains; and increased consumption of meat and meat products, dietary products, edible oils, salt, and sugar, and a lower intake of dietary fiber. One consequence of a narrowing base of staple grains is a loss in biodiversity with the potential of threated food security. More specifically, the shift to a diet higher in fats, edible oils, salt and sugar has led to the spread of non-communicable diseases.

The purpose of this thesis is to explore cross-country dietary convergence in terms of total calories and the proportion of total calories from animal products, cereals, crops oils, sweeteners, pulses, fruits, vegetables and roots. The study examines data for 152 countries from 1961 to 2009 using two convergence indicators: β- and σ-convergence. β-convergence refers to countries with higher (lower) initial amount of per-capita of food consumption, measured in calories, in total or by source, which experience slower (faster) growth than countries with lower (higher) initial amounts. This convergence is assessed by the sign and statistical significance of the coefficient on the initial values. In contrast, σ-convergence refers to a narrowing of spread of calories, in total or by source, across countries and time. The presence of σ-convergence is measured via the magnitude of the coefficient of variation.

Using nonlinear least squares (NLS), an extended regression model of growth in calories included *Latitude* as a proxy for differences in climate, vegetation, and historical development. If β-convergence exists the estimated coefficient of β must be positive. However, suspecting heteroscedasticity, the Breusch-Pagan and White tests are employed when estimating the model. Then, since the form of heteroscedasticity is unknown, a generalized method of moments estimation (GMM) is employed for improving the efficiency of the parameter estimates.

The results of statistical tests for β-convergence are as follows. The results from the White test for heteroscedasticity indicate that the null hypothesis of homoskedasticity for total calories and proportion of calories from eight sources is rejected as all calculated chi-square are greater than the critical value. Under Breusch-Pagan test, on the other hand, the null hypothesis is not rejected for total calories and roots. The point estimates of the β values suggest that the speed of convergence is highest for total calories then followed by crop oils, vegetables, cereals, sweeteners, roots, fruits, animals, and pulses. Results from GMM shows that the coefficients of β-convergence are similar in magnitude and statistical significance to their counterparts using NLS, preserving the rankings in terms of speed of convergence. More specifically, the results of this study confirm the scenario that β-convergence illustrates the higher average growth rates in countries with lower initial calories and a lower rate of increase in countries with higher initial calories.

Results for latitude show that the further countries are located from the equator, the greater average growth of rates for total calories, and the proportions of total calories from animal products, oils, sweeteners, fruits, and vegetables, but not for cereals, roots, and pulses.

Results from the coefficient of variation indicate that σ-convergence is found in total calories and the proportion from eight calorie sources. This finding is consistent with the results from the statistical test of β coefficients which indicates convergence in diet structure across countries.

Findings of convergence reveal that dietary structure across countries is becoming increasingly similar, although at differing speeds, and depending how further away a country is from the equator. Should this translate to continued transformation of developing countries' food systems from traditional to Western-type patterns, one should expect further negative consequences for health in terms of increased incidence in non-communicable diseases; and for the environment, in terms of further degradation and loss in biodiversity.

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